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GAS MEASURING DEVICE

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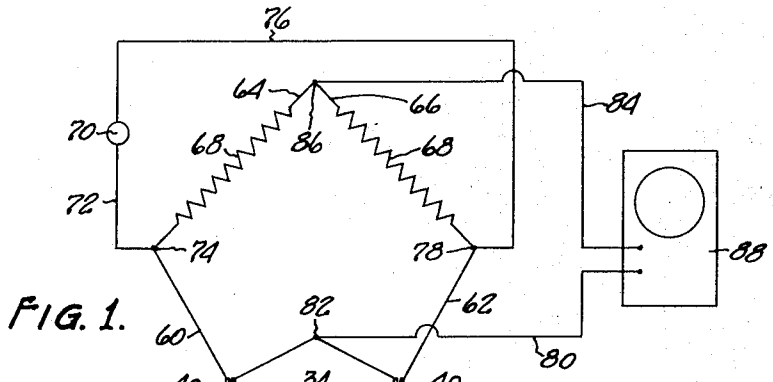
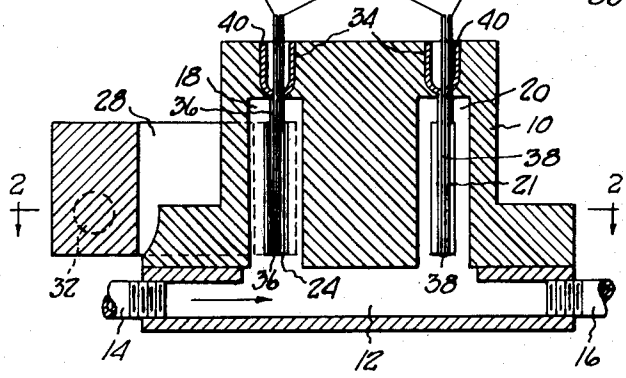



FIG. 1.



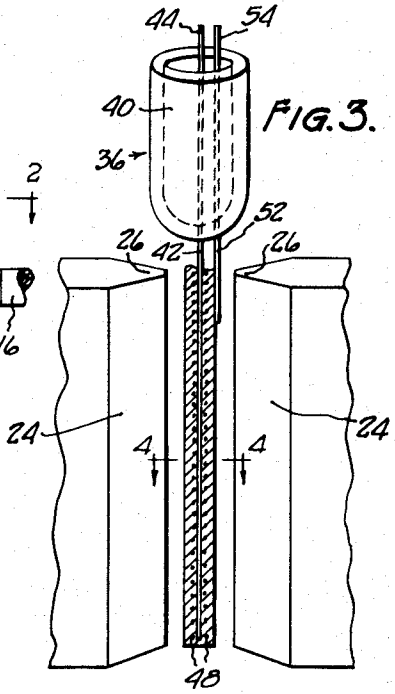




FIG. 3.

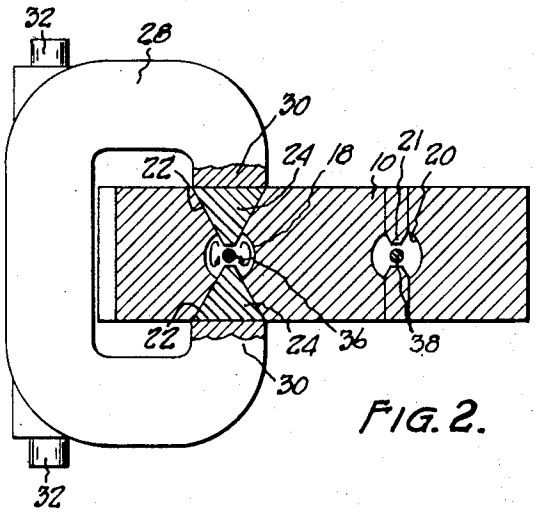



FIG. 2.

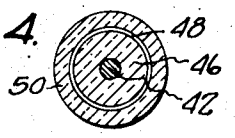



FIG. 4.

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## GAS MEASURING DEVICE

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8 Claims. (Cl. 73—27)

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This invention relates to improvements in gas measuring devices, and more particularly to devices for measuring the oxygen content of a gas sample.

The device utilizes the principle that the paramagnetic properties of oxygen are high compared to all other gases except NO. The device is of the comparison type, having two test chambers of similar characteristics provided with similar electric thermal elements arranged therein. The only difference between the two comparison chambers is in the provision in one of said chambers of means for creating a heterogenous magnetic field. A device of this type is illustrated and described in my co-pending patent application, Ser. 595,569, filed May 24, 1945.

This invention has for its primary object the provision of a device of this character of increased sensitivity and accuracy which is responsive to minute differences or changes in the oxygen content of a gas sample and which provides an improved or increased electrical output for a given percentage of oxygen content being measured, as compared to the output of previous devices utilizing the same operating principle.

A further object is to provide a device of this character having a test cell constructed to increase the cooling effect of the flow of oxygen past a thermal element which is arranged in a heterogenous magnetic field to induce said flow.

A further object is to provide a device of this character having a novel test cell wherein the cooling effect of oxygen on a thermal element in a magnetic field is substantially uniform throughout the full extent of said element.

A further object is to provide a device of this character wherein a thermal element and magnetized pole pieces are so arranged and located in a test chamber for a gas having an oxygen content to be measured that a novel and highly effective flow of gas content to cool the thermal element is obtained.

Other objects will be apparent from the following specification.

In the drawing:

Fig. 1 is a vertical sectional view of the device with parts illustrated diagrammatically.

Fig. 2 is a transverse horizontal view taken on line 2—2 of Fig. 1.

Fig. 3 is an enlarged perspective view illustrating the construction and relation of the heating element and the magnetic pole pieces.

Fig. 4 is a still further enlarged transverse sectional detail view taken on line 4—4 of Fig. 3.

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Referring to the drawing which illustrates the preferred embodiment of the invention, the numeral 10 designates a test cell which preferably constitutes a block of brass or other non-ferrous material. The material of which cell 10 is constructed is preferably selected for its thermal stability and general ruggedness. A longitudinal passage 12 extends through the cell which may be formed of multiple parts, and a gas inlet conduit 14 is connected at one end of said passage 12, and a gas outlet conduit 16 is connected at the opposite end of the passage 12. The gas outlet conduit 16 may be omitted in certain instances. The passage 12 is formed in the cell adjacent one margin thereof, and a pair of substantially similar chambers 18 and 20 are formed in spaced relation within the cell, preferably extending parallel to each other and perpendicular to the passage 12 with which each communicates at one end. In one form found well suited for the purposes of the invention, the chambers 18 and 20 are formed of approximately ½ inch diameter.

The cell 10 has a pair of inwardly tapering elongated slots 22 formed in opposite sides thereof and communicating with the chamber 18 in diametrically opposed relation. These slots each mount an iron pole piece insert 24 of substantially the shape and construction shown in Fig. 3, that is, substantially wedge shaped form. These members are suitably secured within the slots of the test cell and preferably have their outer surfaces terminating flush with the side walls of the test cell, as shown in Fig. 2. The pole pieces 24 are constructed of such size and dimensions that the tips 26 thereof project into the chamber 18, as best illustrated in Fig. 2, and in one preferred form the tips of the magnets are spaced apart approximately $\frac{3}{16}$ of an inch, being blunt at their inner or confronting faces. It will be observed, therefore, that when the pole pieces extend for the major portion of the length of the chamber 18, as illustrated in Fig. 1, they form ribs or restrictions projecting interiorly into said chamber and dividing the same into two substantially similar portions having a restricted gap for communication therebetween. The chamber 20 is preferably provided with non-magnetic inwardly projecting ribs of the same dimension as the pole tips 26 in chamber 18.

A permanent magnet 28, preferably of C-shape as shown in Fig. 2, and having inturned confronting pole portions 30 spaced apart a distance substantially equal to the width of the test cell

10, cooperates with the pole pieces 24. The magnet may be provided with projecting pins 32 parallel to the pole portions 30 adapted to pivotally mount the magnet so that the faces of its pole portions may travel in a plane parallel to the side faces of the test cell 10. It will be understood that the faces of the pole portions 30 of the magnet are so spaced that they have clearance with the side faces of the test cell sufficient to permit pivotal movement of the magnet about the pins 32 without interference or binding. Thus the magnet serves in its operative position illustrated to magnetize the pole pieces 24 when operatively positioned or may be swung to a position clear of said pole pieces, whereby the same are substantially demagnetized.

The test cell has a pair of socket openings 34 formed therein in alignment and in communication with the inner end of each of the chambers 18 and 20. Two heating elements are provided in the device. The element 36 constitutes a measuring element and is positioned in chamber 18. An element 38 constitutes a comparison element and is positioned in chamber 20. The two heating elements are similarly constructed and preferably have substantially the same heating properties. The construction of the heating elements is best illustrated in Figs. 3 and 4. A support 40 is formed of electrical insulating material, such as glass, and may be of cup shape as shown. The support 40 is mounted in one of the openings 34 in the test cell in communication with the correlated chamber thereof, said supports serving to seal and close the openings 34 in which they are mounted. A wire stem 42 extends longitudinally through the support 40 in which it is fixedly secured. The upper portion of the stem 42 projects above the support 40 to provide a terminal 44. The lower portion of the stem 42 projects below the support 40 and supports a glass tube or sheath 46 which is melted in place therearound. A coil of wire 48 is connected to one end of the stem 42 and is wound around the sheath 46 of the stem 42. The entire unit so formed is then glazed with glass of the same type used for the sheath 46 to provide an outer coat or sheath 50. A second wire stem 52 extends longitudinally through and is anchored to the support 40 in spaced relation to the stem 42. The upper end of stem 52 projects above the support 40 to provide a terminal 54. The lower end portion of the stem 52 is secured to the glazed coat 50, whereby it cooperates with the stem 42 to support the depending heater unit in desired position with relation to the support 40. The coil 48 is connected at its upper end to the stem 52 and at its lower end to the stem 42. The length of the depending heater portion of each heating element is preferably such that it extends substantially the full length of that one of the chambers 18 and 20 in which it is positioned, as best shown in Fig. 1. The two heating elements 36 and 38 are preferably positioned centrally within their associated chambers 18 and 20, respectively, and the heating element 36 preferably extends parallel to and between the confronting faces of the tips of the pole pieces 24, as illustrated in Figs. 2 and 3. In one form of the device in which the spacing of the magnets is approximately $\frac{3}{16}$ of an inch, a heating element of .025" diameter was used, positioned substantially equi-spaced from the confronting tip faces of the pole pieces and between the same, said top faces being ¼" wide.

The terminals 44 and 54 of the two heater elements are connected in separate legs 60 and 62 of a Wheatstone bridge circuit whose remaining legs 64 and 66 have balanced impedances or resistances 68 interposed therein. The bridge circuit is connected to any desired source of power 70, which may be either direct current or alternating current, by lead 72 connected to point 74 between the legs 60 and 64 of the bridge, and by lead 76 connected to point 78 of the bridge between the legs 62 and 66. A lead 80 is connected to the bridge at point 82 between the legs 60 and 62, and a lead 84 is connected to the bridge at point 86 between the legs 64 and 66. The two leads 80 and 84 are connected to a device 88 which is to be operated, which device may be either a recorder or an indicator and which preferably, in the case of the recorder at least, is provided with a suitable amplifier.



In the operation of the device, the gas to be tested is supplied by the conduit 14 and discharged thereby into the passage 12. The oxygen content of this gas is attracted into the heterogeneous magnetic field surrounding the heating element 36 in the chamber 18 by reason of the paramagnetic properties of the oxygen. As the gas comes into contact with or within the thermal influence of the heating element 36, it is heated by said element. The heating of the oxygen causes it to lose its attraction to the magnetic field. Consequently, the comparatively cool oxygen from passage 12 continually displaces the heated oxygen in the area in the chamber 18 immediately adjacent the heating element 36 and a net flow of gas is maintained. Gas from the passage 12 likewise enters the chamber 20 and is heated therein in the same manner but without the influence of a magnetic field.

By virtue of the properties of oxygen in a magnetic field, that is, the attraction of cool oxygen to a magnet and the loss of such attraction upon heating thereof, the rate of flow of gas in the chamber 18 and along the heating element 36 is greater than the rate of flow in the chamber 20 around the heating element 38 thereof. This increased gas flow serves to cool the heating element 36 somewhat, thereby changing the electrical value of the heating element 36 compared to the same value of the element 38 and unbalancing the normally balanced bridge circuit to permit operation of the recorder or other instrument 88 in direct proportion to the percentage of oxygen present in the gas sample. If there is no oxygen present in the system to be influenced by the magnetic field, the flow of gas in the two chambers 18 and 20 will be the same, and the two heating elements 36 and 38 operate in balanced relation.

The arrangement and shape of the chamber 18, the pole pieces 24 and the substantially coextensive relation of the pole pieces with respect to the heating element positioned therebetween are important features of this invention. This arrangement insures that substantially the full length of the heating element 36 will be within and subject to the direct influence of the magnetic field. Consequently, the gas flow and its cooling action upon the heating element is substantially uniform throughout the full length of the heating element, thereby producing a greater effect, considered electrically, than in my previous device. In other words, the measurable electrical effect, when comparing the two heating elements 36 and 38, is great, thus affording a greater unbalance of the bridge for any given percentage

of oxygen in the gas, thereby increasing the sensitivity of the device, making measurement of small changes in oxygen percentage possible, and in general improving very materially the stability, sensitivity and accuracy of the device. In one embodiment of the invention more than 60 millivolts unbalance at the bridge was obtained, as between the two heating elements **36** and **38**, for a sample of air. This is much greater unbalance than has been obtainable by previous devices, and it will be apparent, therefore, that as the percentage of oxygen in a gas sample is reduced compared to the percentage of oxygen in air, there still remains a substantial range between zero millivolts and 60 millivolts for measurable and distinct unbalance proportional to the existing oxygen content of the gas sample being measured.

It is interesting also to note that in a construction of this character the gas attracted into the magnetic field is caused to swirl transversely in the chamber, as illustrated by the arrow in Fig. 2. This combined longitudinal and transverse flow of gas in the test chamber produces a substantial cooling effect upon the heating element **36** which has been described and which produces the enhanced cooling effect. Such swirling action occurs through substantially the fully length of the chamber, due to the location of the magnets to extend substantially the full length of said chamber and substantially coextensive with the length of the heating element, as best seen in Fig. 3.

The provision of the ribs **21** in the chamber **20** insures that the dimensions and shape of the chamber **20** will be the same as the dimensions and shape of the chamber **18**. The ribs are preferably formed of brass or some non-magnetic material which has substantially the same heat transfer properties as the iron of pole pieces **24**. Consequently, the same cooling effect inherent in the structure as a result of the formation of the parts from heat conducting material is assured, and the only difference in the cooling action is the result of the increased flow of gas around and with respect to the heating element **36** resulting from the magnetic properties of the oxygen content of the gas. It will be understood, however, that the use of the ribs **21** is optional and not essential inasmuch as the balance of the bridge can be effected to compensate for any difference in the cooling action of the parts of the block upon the two heating elements.

While the preferred embodiment of the invention has been shown and described herein, it will be understood that changes may be made within the scope of the appended claims without departing from the spirit of the invention.

I claim:

1. In a gas measuring device, a test cell formed of non-magnetic material, said cell having a gas passage and a pair of chambers communicating with said passage, a pair of similar elongated rigid electric heating elements each projecting into one of said chambers, each of said chambers having a longitudinally extending portion of reduced transverse dimension in which one of said elements is positioned, the reduced dimension longitudinal portion of one chamber being magnetizable, the other chamber being of such size and volume and having a heating element so located therein that the heat transfer which occurs therein balances the heat transfer which occurs in the first chamber when not magnetized, inserts carried by said cell and formed of material defining a magnetic flux path projecting into said one chamber to define said reduced dimension, and means for creating a magnetic field in and between said last named inserts, said inserts being substantially coextensive with the length of the element juxtaposed thereto.

2. In a gas measuring device, a test cell formed of non-magnetic material, said cell having a gas passage and a pair of chambers communicating with said passage, a pair of similar elongated rigid electric heating elements each projecting into one of said chambers, one of said chambers having a pair of elongated magnetizable ribs projecting therein and parallel to and in substantially diametrically opposed relation to the heating element in said chamber, and means for creating a magnetic field around said last named element along the major portion of its length, the other chamber having a cross-sectional size and a relation to said heating element such that a heat transfer occurs therein similar to the heat transfer occurring in the first chamber when not magnetized.

3. In a gas measuring device, a test cell formed of non-magnetic material and having a gas passage and a pair of chambers communicating with said passage, a pair of magnetizable members carried by said cell and projecting into one of said chambers to terminate in spaced confronting relation, said members extending substantially the full length of said chamber, and a pair of similar heating elements carried by said cell and each projecting into one of said chambers, one of said elements being positioned substantially parallel to and between the confronting portions of said members.

4. In a gas measuring device, a test cell formed of non-magnetic material and having a gas passage and a pair of chambers communicating with said passage, a pair of magnetizable members carried by said cell and projecting into one of said chambers to terminate in spaced confronting relation, said members extending substantially the full length of said chamber, and a pair of similar rigid electric heating elements carried by said cell and each projecting into one of said chambers, one of said elements being positioned substantially parallel to and between the confronting portions of said members, the projecting portions of said members tapering inwardly and said heating element being spaced therefrom a small distance compared to its spacing from the remaining surfaces of said chambers.

5. In a gas measuring device, a test cell formed of non-magnetic material and having a gas passage and two elongated chambers communicating with said passage, one chamber comprising parallel elongated cavities open at one end at said passage and communicating for substantially the full length thereof through a restricted gap, inserts formed of magnet-flux-transmitting material carried by said cell and projecting into said chamber to define said restricted gap, an elongated rigid electric heating element in each chamber, said elements being comparable, the element in said last named chamber being positioned in said gap, and means for subjecting said inserts to magnetic flux and for creating a magnetic field in said gap, the other chamber having a size and arrangement such as to produce a heat transfer balancing the heat transfer occurring in the first chamber when no magnetic flux occurs in said first chamber.

6. In a gas measuring device, a test cell formed of non-magnetic material and having a gas passage and two elongated chambers communicating

with said passage, one chamber comprising parallel elongated cavities open at one end at said passage and communicating for substantially the full length thereof through a restricted gap, inserts formed of magnet-flux-transmitting material carried by said cell and projecting into said chamber to define said restricted gap, an elongated rigid electric heating element in each chamber, said elements being comparable and each including spaced juxtaposed leads connected at one end, the element in said last named chamber being positioned in said gap, and means for creating a magnetic field in said gap, said field being of substantially uniform strength throughout the length of said gap, the other chamber being of such size, shape and relation to its contained heating element as to produce heat transfer therein corresponding to heat transfer occurring in said first chamber.

7. In a gas measuring device, a test cell formed of non-magnetic material and having a gas passage therethrough and two elongated chambers therein open only at said passage, an elongated rigid electric heating element fixedly carried by said cell and extending substantially full length in each chamber, and means for creating a magnetic field around at least the major portion of the element in one of said chambers, said last named chamber having inwardly projecting lon-



gitudinal ribs defining a cross-sectional shape adapted to cause gas having an oxygen content to move therein in a combined longitudinal and transversely swirling motion in substantially proportional response to the effect of said magnetic field upon the oxygen content of the gas, said heating element being positioned between and substantially equally spaced from said ribs.

8. The construction defined in claim 3 wherein the other chamber has a pair of non-magnetizable projections extending therein and similar in size, shape and location to the magnetizable members in said first chamber.

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